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Development and seedling establishment within a *Juniperus communis* stand on Öland, Sweden

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SUMMARY

Development and regeneration in an expanding *Juniperus communis* stand was recorded in two permanent plots (each 50 × 50 m) during 1970/71–1986. One plot was cleared, showing an uneven age distribution: 14–116 years (seedlings not included). In the uncleared control plot the juniper stand increased its cover from 10·0 to 18·3% (1971–1986). Young shrubs increased more in height and diameter than older ones. Seedling establishment was recorded in the two plots from 1971 and in a cattle-grazed plot from 1983. The latter had the highest number of seedlings (814) but also the highest mortality (24%) due to drought. Aggregations of seedlings were found in areas between old shrubs. Correlation between stem diameter and age was calculated ($r = 0{\cdot}84$).

Key-words: age distribution, conservation, juniper scrub, regeneration, shrub expansion.

INTRODUCTION

Regeneration, growth and longevity of *Juniperus communis* have been frequently studied (Ward 1973, 1981, 1982; Fitter & Jennings 1975; Gilbert 1980; Faliński 1980; Rosén 1982). Microhabitat studies related to microclimatic conditions have been done by Barkman *et al.* (1977) and microhabitats, sex ratios, etc., in connection with succession, have been described by Faliński (1986). A central European classification of *Juniperus communis* associations was presented by Barkman (1985), later accomplished for fungal communities (Barkman 1987).

The present paper deals with a part of a larger project about the expanding juniper vegetation on the island of Öland, Sweden, Additional information is given by Rosén (1988), Rosén & Sjögren (1988) and Rejmánek & Rosén (1988). The main aims of this research were to follow juniper expansion in the *Veronica spicata–Avenula pratensis* association (Krahulec *et al.* 1986), especially (1) to study the development of a *Juniperus communis* stand in terms of growth, regeneration and establishment patterns—combined with survival and (2) to search for differences in development between a cattle-grazed and an ungrazed area.

RESEARCH SITE

The research area is located in the north-east part of the so-called Stora Alvaret, which is a limestone plateau originating from the Ordovician period of sedimentation. The plateauing

Fig. 1. *Juniperus communis* vegetation in Stora Alvaret, growing on littoral deposits. Both erect and prostrate junipers are found in the grassland vegetation classified as *Veronica spicata–Avenula pratensis* association. View from the north-east part of the ungrazed-uncleared (control) plot (50 × 50 m). Alvar of Nedre Ålebäck. September 1987.

is mainly covered with shallow calcareous soils (54%), but also with somewhat deeper littoral deposits (silicate soils) covering about 26% of the area (Enckell *et al.* 1979).

From a Scandinavian point of view the area has a low precipitation with a mean value of 437 mm (1965–1984); showing considerable variation between years and also within years. The area has about 2000 sunshine hours per year. There is a high wind frequency with southwesterly winds predominating throughout the year. In combination these circumstances cause high evaporation, thus making the plant cover dependent on soil depth and precipitation. The mean annual temperature is 7·0–7·2°C (Eriksson 1982).

The thin soils of the Alvar are mainly regulated by drought and frost heaving, while grazing and (in older days) cutting for firewood created and maintained open grassland communities in places with deeper littoral deposits. In the 19th century the Alvar became heavily overgrazed. Grazing and wood-cutting decreased at the end of the century, resulting in an expansion of trees and shrubs in the area (Rosén 1982).

This expansion, mainly by *Juniperus communis,* takes place on old beach-ridges where the soil depth usually is within the range 0·2–0·5 m. The juniper vegetation in these sites seems to be related to the *Dicrano–Juniperetum* association as described by Barkman in 1985 (Rosén & Sjögren 1988). The junipers in the area include both erect and prostrate types (Fig. 1). According to Turesson (1961) most of these are probably genotypical variants. However, in these wind-exposed areas there may also be phenotypical modifications.

METHODS

In order to measure the standing crop of a juniper stand, and to study regeneration and growth, two permanent plots (50 × 50 m) were laid out and fenced in 1970/71. All junipers were mapped and their height and two crossing diameters were measured. On the basis of the largest of the two diameter values the shrubs were separated into four size classes (I–IV), with diameters: 0–1, 1·05–2, 2·05–3 and ⩾3·05 m, respectively (Rosén 1982). After some years it was discovered that several shrubs in class IV actually included two or three individuals, while only very few of that kind were found in classes II and III, and none in class I. In some cases it is very difficult to decide (without digging) whether we are dealing with an individual or an aggregation of shrubs. The possibility of clonal growth (mentioned by several authors, e.g. Ward 1982) with adventitious roots formed from branches of prostrate shrubs may complicate the situation. Considering these 'shrubs' as growing units for measurements of expansion (diameter and height) it was decided to keep the original distinction of individuals. These plots were then recorded with 5-year intervals until 1986 (and each year in 1983–1985). Basic information about these plots have been reported by Rosén (1982).

In one of the plots all junipers were measured, with the exception of 65 very small ones only counted before the area was cleared. Year-ring countings were done on the 136 larger ones. This plot is referred to as 'ungrazed-cleared'. The second plot was a control plot 'ungrazed-uncleared'. In 1983 a third plot was laid out close to the fenced plots. That plot, 'grazed-uncleared', has been moderately cattle grazed (heifers) since the first two plots were established and fenced. In all plots seedlings were recorded parallel with the other measurements. In uncleared plots the first recordings of seedlings also include some slightly older individuals, all however referred to as seedlings.

RESULTS

The cover of *Juniperus* shrubs was 11% in 1970 before the plot was cleared and consisted of 136 shrubs and 65 very young ones. These 136 junipers showed clear variation in age with a range from 14 to 116 years (Rosén 1982). The correlation between age and largest basal stem diameter, while excluding the four 'outlayers' 14, 91, 108 and 116 years and five with damage on the trunk, is very high for the interval 20–90 years ($r = 0{\cdot}84$) (Fig. 2).

As year-ring counting on 65 very young individuals could not be done, there is an under-representation for the lowest ages. Only three shrubs were older than 90 years (91, 108 and 116 years). This reflects the very open character of the landscape in the 19th century, which has been reported both in the literature and by the older generation (Rosén 1982). In this uneven-aged stand the most frequent age values are around 30–40 years. This is probably related to a lower grazing intensity in the area around 1930–1940 (Rosén 1982).

The individual mapping of junipers in 11 age classes enables us to check where colonization took place within the plot (Fig. 3). The younger junipers (classes 2–4) show clear aggregation, which is less pronounced for older ones (5–7), while the oldest junipers (8–11) are scattered. Such aggregations of juniper seedlings have also been reported from Poland (Faliński 1980). Another pattern, which may be related to edaphic factors, has the form of small concentrations of shrubs intermingled with relatively large open areas. The central

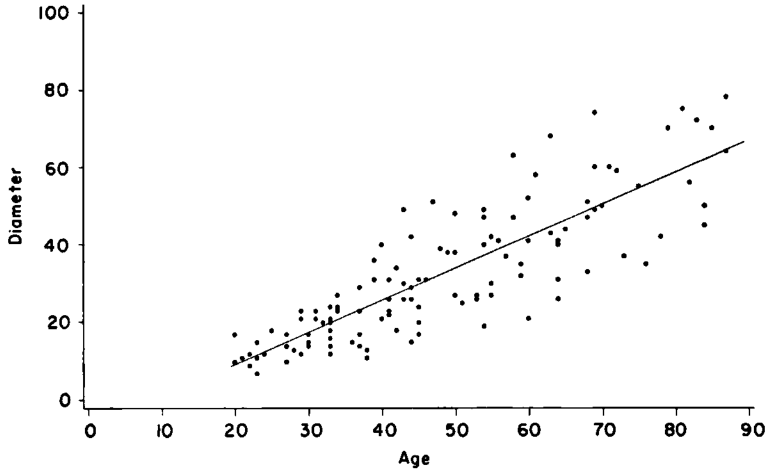

Fig. 2. Diagram showing the relation between age (years) and largest stem diameter (mm) within the interval 20–90 years in a *Juniperus communis* stand. Plot size: 50 × 50 m, no. shrubs: 127, correlation value: $r = 0{\cdot}84$, regression equation: diameter $= -7{\cdot}28 + 0{\cdot}82 \times$ age.

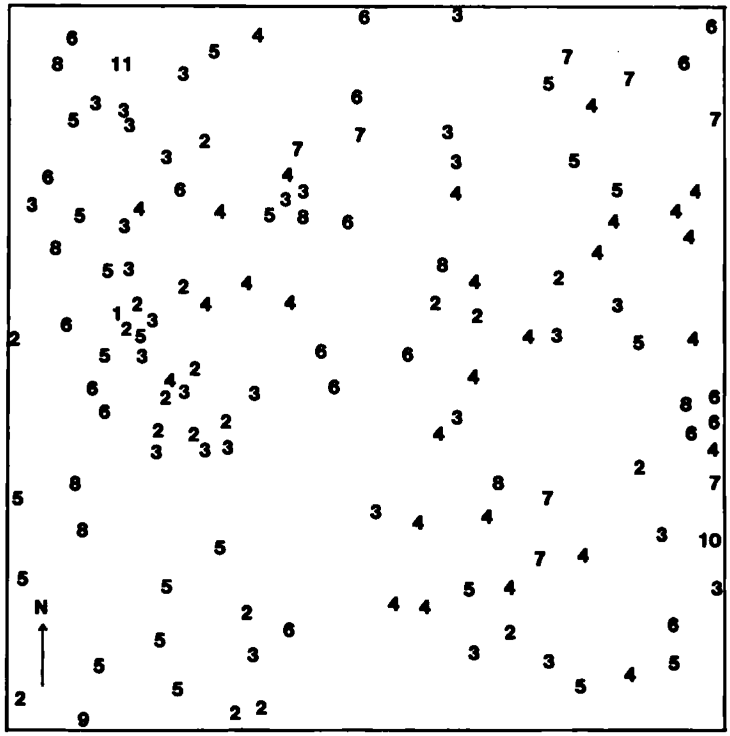

Fig. 3. Distribution of age classes of *Juniperus communis* in the ungrazed-cleared plot (50 × 50 m) in 1970. 1 = 10–19 years, 2 = 20–29, etc. Within brackets number of shrubs in each class: 1 (1), 2 (19), 3 (29), 4 (28), 5 (21), 6 (19), 7 (8), 8 (8), 9 (1), 10 (1), 11 (1). Total = 136 shrubs.

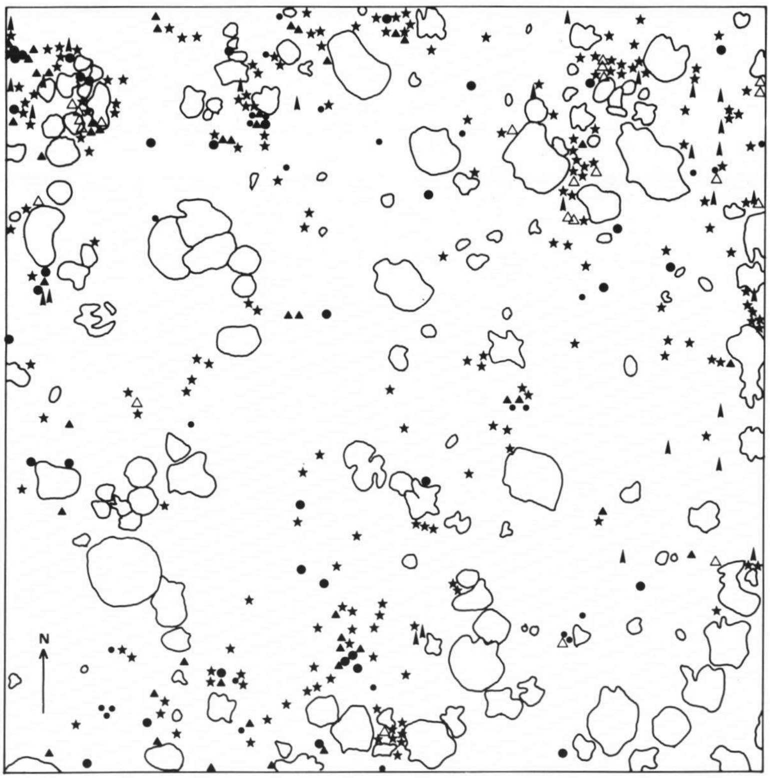

Fig. 4. Distribution of old junipers (1971) and established seedlings in the ungrazed-uncleared (control) plot (50 × 50 m): 1971 (●), 1976 (▲), 1981 (•), 1983 (★), 1984 (△) and 1985 (▲). Only shrubs and seedlings still living are included. Alvar of Nedre Ålebäck.

Western part seems to be especially favourable for seedling establishment (cf. Rosén 1982, fig. 22).

Seedling establishment, as well as growth of the older shrubs, was investigated with 5-year intervals in the control plot. The new seedlings in the control plot are shown, together with the shape of the junipers in 1971 (Fig. 4). From 1983 to 1985 seedlings were mapped annually in all plots. Aggregations are seen very clearly but there is also a colonization pattern in the openings between shrubs. Gilbert (1980) stated that in 15 years he had never seen a young juniper grow within the root-spread of a parent bush. Such a statement is irrelevant for the present plots because in the shallow soils in the Alvar juniper roots may be very widespread. Roots of 4–5 m length may be found in thin soils being lifted up to the surface by frost heaving. Few new seedlings were recorded until 1981, while very high numbers of seedlings were found in 1983 in all plots (Table 1). The increase in seedlings in certain periods is a result of favourable conditions for establishment; a situation that is also mentioned by Ward (1981). Periods of such conditions for establishment are mentioned for the Western juniper (*Juniperus occidentalis*) within sagebrush communities in California by Young & Evans (1981).

In the grazed-uncleared plot, 814 seedlings were found in 1983. This is considerably higher than in the ungrazed-uncleared plot, with only 317 seedlings. As there is no visible difference between these plots this difference must be related to effects of grazing.

Table 1. Number of junipers (old, young/seedlings and total) from 1970/71 to 1985 in three 50 × 50 m permanent plots: ungrazed-cleared, ungrazed-uncleared and grazed-uncleared (from 1983). Clearing was done in autumn 1970. Detailed mapping: 1983–1985

	Ungrazed-cleared			Ungrazed-uncleared			Grazed-uncleared		
Plot	Old	Young/ seedlings	Total	Old	Young/ seedlings	Total	Old	Young/ seedlings	Total
1970/71	136	65	201	150	40	190	—	—	—
				−1					
1976	—	107	107	149	88	237	—	—	—
		−1		−1	−3				
		+53		+1	+28				
1981	—	159	159	149	113	262	—	—	—
					−1				
		+447			+205				
1983	—	608	606	149	317	466	130	814	944
		−47			−12			−233	
		+45			+21			+36	
1984	—	604	604	149	326	475	130	617	747
		−7			−5			−7	
		+84			+28			+15	
1985	—	681	681	149	349	498	130	625	755

The ungrazed-cleared plot showed an intermediate number of seedlings (606). Although there were 40 seedlings in the uncleared plot and none in the cleared one from the beginning, the figures from 1976 onwards were much higher for the cleared plot.

Due to severe drought in 1983, 47 (cleared) and 12 (uncleared) seedlings were killed in the ungrazed plots, but the grazed plot lost 233 seedlings (24%) between 1983 and 1984.

Measurements in the ungrazed-uncleared plot show that the mean height of the stand increased from 65 to 100 cm (54%) in the period 1971–1986. In the same plot the cover of *Juniperus* was 10·0% in 1971. Subsequent figures were 12·1% (1976), 14·5% (1981) and 18·3% (1986), which shows accelerated increase. Thus the stand has increased by 83% during the 15-year period. Seedlings are not included here, since they cover less than 0·5%.

The grazed-uncleared plot had a juniper cover of 15·2% (1983) and 17·6% in 1986 showing a fairly similar cover to that in the ungrazed-uncleared plot.

Calculations of the percentage increase in height and diameter for the four size classes are shown in Table 2. Generally the small shrub classes show a higher increase, both in height and diameter, than the larger ones (Rosén 1982). This pattern is also shown for the interval 1981–1986, but with somewhat higher percentages for diameters than before, and with much higher values for height increase. The figures for height have increased for each 5-year interval.

DISCUSSION

The mapping clearly shows that seedlings establish more frequently in the open spaces between older shrubs than close to them; either as individuals or aggregated. Birds, e.g. thrushes, are considered to play an important role in seed dispersal, although Vedel (1961)

Table 2. The percentage increase in diameter and height for junipers in the ungrazed-uncleared plot (50 × 50 m) within four diameter classes

Class	I	II	III	IV
1971–1976				
Height	18	7	7	4
Diameter	27	11	7	5
1976–1981				
Height	25	14	8	6
Diameter	20	11	7	5
1981–1986				
Height	42	30	21	21
Diameter	23	17	9	9

also mentioned hares and sheep as possible dispersal agents. Ward (1973) also considered it likely that birds are important but points out that still very little is known about dispersal factors; she mentioned that junipers are often associated with sheep walks. Another dispersal possibility on Öland is formed by the strong winds frequent in winter. If combined with frozen snow cover, diaspores certainly will spread over long distances. Assuming that dispersal is fairly even, growth and survival conditions are more essential for the future pattern than dispersal. A strong competition for water (between juniper seedlings, field layer and old shrubs) may well take place close to mature juniper bushes, co-inciding with the drier conditions on southern sides of shrubs observed by Barkman *et al.* (1977). This could partly explain the rare presence of seedlings close to old junipers.

The importance of grazing for germination of *Juniperus communis* was reported by several authors, e.g. Vedel (1961), Ward (1973), Fitter & Jennings (1975), Gilbert (1980), and for *Juniperus osteosperma* in Nevada by Blackburn & Tueller (1970).

The conclusion drawn from the Öland plots is that the establishment of seedlings was favoured by grazing, in this case moderate cattle grazing. Conversely, a much higher number of seedlings was killed by severe drought in 1983 in the grazed plot, than in the ungrazed ones, as the dense sward probably protected the seedlings from drought in the latter. Thus grazing creates a stronger dynamic situation for juniper seedlings compared with ungrazed areas. On shallow soils the location of seedlings is highly decisive for their survival. This was shown in another plot where many shrubs were killed by drought, while others survived two extremely dry periods (Rosén 1984, 1985). The same plot also indicated very good years for junipers around 1979–1980, which may be a reason for the high numbers of seedlings recorded in all plots in 1983. It is difficult to select a major factor for successful seedling establishment as there is most likely a combination of factors involved that relates to local conditions and fluctuations in the plant cover. The slow growth of young seedlings may be caused by suppression by grazing (Fitter & Jennings 1975; L. K. Ward personal communication), but also by injuries after a period of drought.

Diameter–age correlation measurements may be a good method for age estimations in fairly even-aged stands growing under good conditions on deeper soils. On shallow alvar, soil presence of fissures in the bedrock will be important for water availability and thus influence the growth rate. This may then create a large variation in the material: in the present case a stem diameter of 50 mm may represent ages between 45 years and 85 years. I support Ward (1982) in a restrictive use of the correlation method as there may be extreme variations amongst individuals in a site.

The results from the ungrazed-uncleared plot show an accelerating expansion of junipers, which is most pronounced for the smaller size classes (both height and diameter increase). The increased rate of height growth is difficult to explain but it may be related to more favourable moisture conditions for growth when the stand becomes denser. The expansion of the juniper scrub is pronounced on large areas within Stora Alvaret. Decreased grazing and absence of cutting for firewood may, in places with good conditions, create more even-aged stands, as are found in Britain. At present most stands have a wide range of ages.

On Stora Alvaret the vigorous expansion of juniper shrub is a conservation problem. The shrub will take over the best areas for grazing and at the same time decrease the extension of the species-rich *Veronica spicata–Avenula pratensis* association.

The investigations reported here contribute to the planning of future use/management of the limestone grasslands of Stora Alvaret, where maintained grazing and shrub clearings are considered essential.

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